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(54) **METHODS AND SYSTEMS FOR CONTROLLING AN ULTRASONIC HANDPIECE BASED ON SENSED PRESSURE**

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A61B 17/00	(2006.01)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

CPC B06B 1/00; B06B 3/00; G10K 11/00; A61B 2017/00106

USPC 600/437, 438, 336, 459; 601/2; 73/584–648; 367/87

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,027,559 A		6/1977	Wallrafen
4,651,716 A		3/1987	Forester et al.
4,750,902 A		6/1988	Wuchinich et al.
5,242,385 A		9/1993	Strukel
5,391,144 A		2/1995	Sakurai et al.
5,514,086 A		5/1996	Parisi et al.
5,674,235 A		10/1997	Parisi
5,796,007 A		8/1998	Panagotopulos et al.
5,897,569 A		4/1999	Kellogg et al.
5,938,677 A	*	8/1999	Boukhny et al. 606/169

(Continued)

OTHER PUBLICATIONS

Non-Final Office Action dated Jan. 5, 2015 relating to U.S. Appl. No. 13/495,728, 21 pages.

(Continued)

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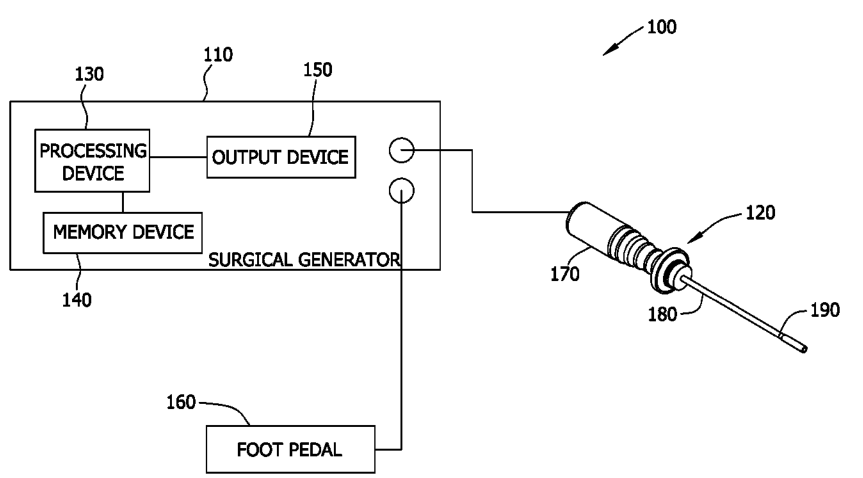
(57) **ABSTRACT**

A system includes a handpiece configured to generate vibratory energy, and a generator coupled to the handpiece. The generator includes a processing device and a memory device having encoded thereon computer-readable instructions that are executable by the processing device to perform functions including receiving a pressure signal from the handpiece. The pressure signal is indicative of a pressure between the handpiece and a surgical implement. The functions further include determining the pressure between the handpiece and the surgical implement, comparing the pressure to a predetermined pressure range, and transmitting a control signal to the handpiece when the pressure is within the predetermined pressure range.

17 Claims, 4 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,968,060	A	10/1999	Kellogg	
5,997,533	A	12/1999	Kuhns	
6,017,354	A	1/2000	Culp et al.	
6,028,387	A	2/2000	Boukhny	
6,053,906	A	4/2000	Honda et al.	
6,217,591	B1 *	4/2001	Egan et al.	606/144
6,352,532	B1	3/2002	Kramer et al.	
6,425,865	B1	7/2002	Salcudean et al.	
6,475,215	B1 *	11/2002	Tanrisever	H05H 1/24 606/32
6,494,095	B1	12/2002	Wan	
6,602,193	B2	8/2003	Chon	
6,678,621	B2	1/2004	Wiener et al.	
6,679,899	B2	1/2004	Wiener et al.	
6,817,973	B2	11/2004	Merril et al.	
7,063,692	B2 *	6/2006	Sakurai	A61B 17/320068 600/101
7,235,072	B2	6/2007	Sartor et al.	
7,273,483	B2	9/2007	Wiener et al.	
7,313,949	B2	1/2008	Yorita et al.	
7,476,233	B1	1/2009	Wiener et al.	
7,758,547	B2	7/2010	Tonelli et al.	
7,776,027	B2	8/2010	Manna et al.	
8,057,480	B2	11/2011	Dorawa et al.	
2002/0049464	A1	4/2002	Donofrio et al.	
2004/0115591	A1 *	6/2004	Warner	433/98
2004/0211260	A1 *	10/2004	Girmonsky et al.	73/579
2004/0267134	A1	12/2004	Hossack et al.	
2005/0288659	A1	12/2005	Kimura et al.	
2006/0229514	A1	10/2006	Wiener	
2006/0235424	A1	10/2006	Vitale et al.	
2007/0016235	A1	1/2007	Tanaka et al.	
2007/0031780	A1 *	2/2007	Warner et al.	433/101
2007/0083209	A1	4/2007	Schenberger et al.	
2007/0123769	A1	5/2007	Fuller et al.	
2007/0196784	A1 *	8/2007	Bochi	A61B 17/1626 433/114
2008/0014627	A1	1/2008	Merchant et al.	
2008/0039845	A1 *	2/2008	Bonutti et al.	606/62
2008/0103515	A1 *	5/2008	Wiener	606/169
2009/0024161	A1 *	1/2009	Bonutti	A61B 17/0401 606/213
2009/0036913	A1	2/2009	Wiener et al.	
2009/0098507	A1	4/2009	Kirstgen	
2009/0124585	A1	5/2009	Cross et al.	
2009/0222037	A1	9/2009	Babaev et al.	
2009/0275864	A1	11/2009	Hirai	
2010/0004585	A1	1/2010	Boukhny et al.	
2010/0004586	A1	1/2010	Boukhny et al.	
2010/0094321	A1	4/2010	Akahoshi et al.	
2010/0174336	A1	7/2010	Stein	
2015/0099966	A1	4/2015	Young et al.	

OTHER PUBLICATIONS

Non-Final Office Action dated Dec. 19, 2014 relating to U.S. Appl. No. 13/495,742, 26 pages.

Final Office Action dated Feb. 2, 2016 relating to U.S. Appl. No. 13/495,728, 9 pages.

Final Office Action dated Feb. 11, 2016 relating to U.S Appl. No. 13/495,742, 17 pages.

Non-Final Office Action dated Aug. 25, 2015 relating to U.S. Appl. No. 13/495,728, 13 pages.

Non-Final Office Action dated Apr. 28, 2015 relating to U.S. Appl. No. 13/495,742, 14 pages.

Non-Final Office Action dated Apr. 22, 2015 relating to U.S. Appl. No. 13/495,728, 17 pages.

Non-Final Office Action dated Aug. 25, 2015 relating to U.S. Appl. No. 13/495,728, 21 pages.

Non-Final Office Action from U.S. Appl. No. 13/495,728, Jul. 14, 2016, 10 pages.

Non-Final Office Action for U.S. Appl. No. 13/495,742, Aug. 25, 2016, 17 pages.

* cited by examiner

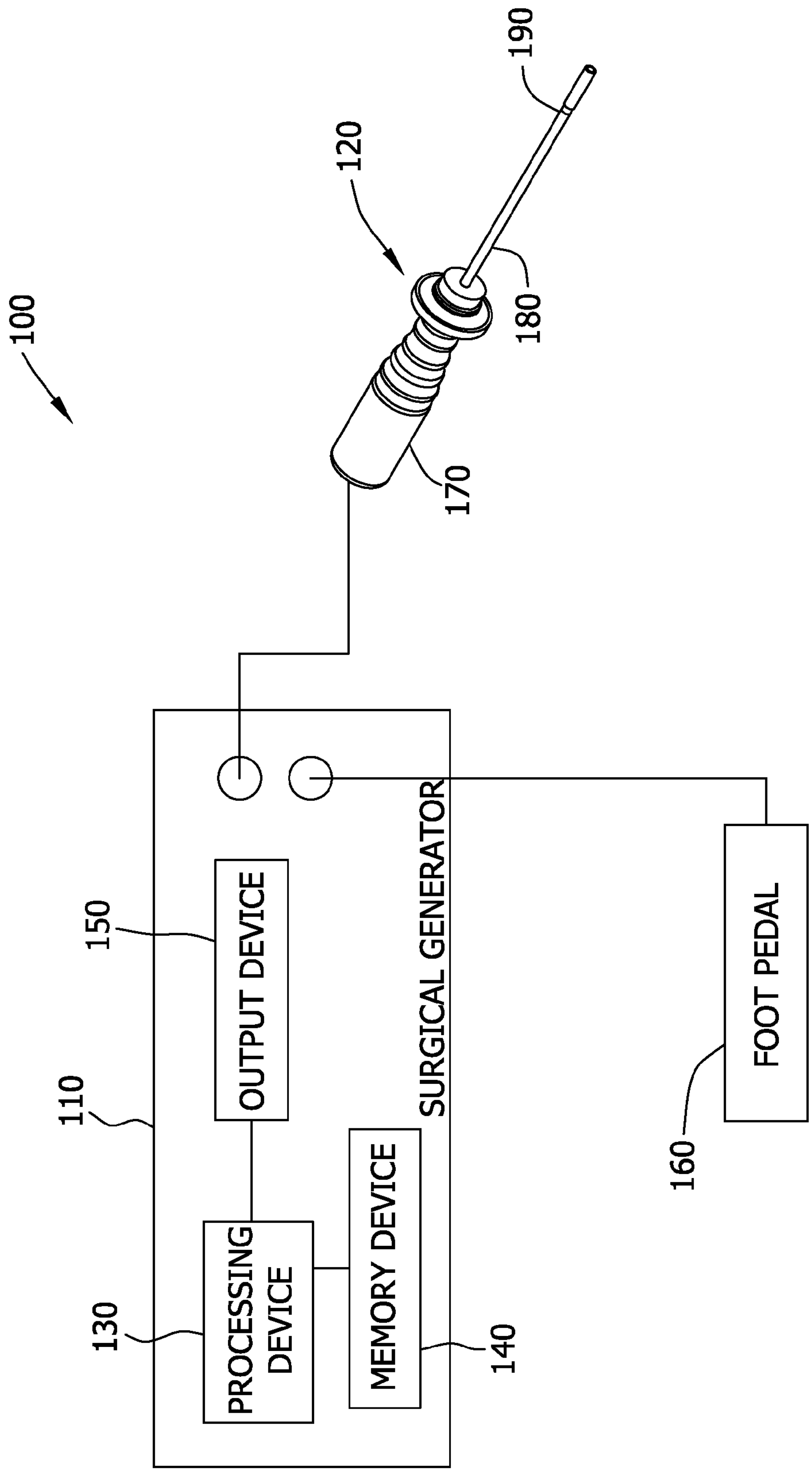

100
120
190
180
170
150
OUTPUT DEVICE
110
SURGICAL GENERATOR
130
PROCESSING DEVICE
MEMORY DEVICE
140
FOOT PEDAL
160

FIG. 1

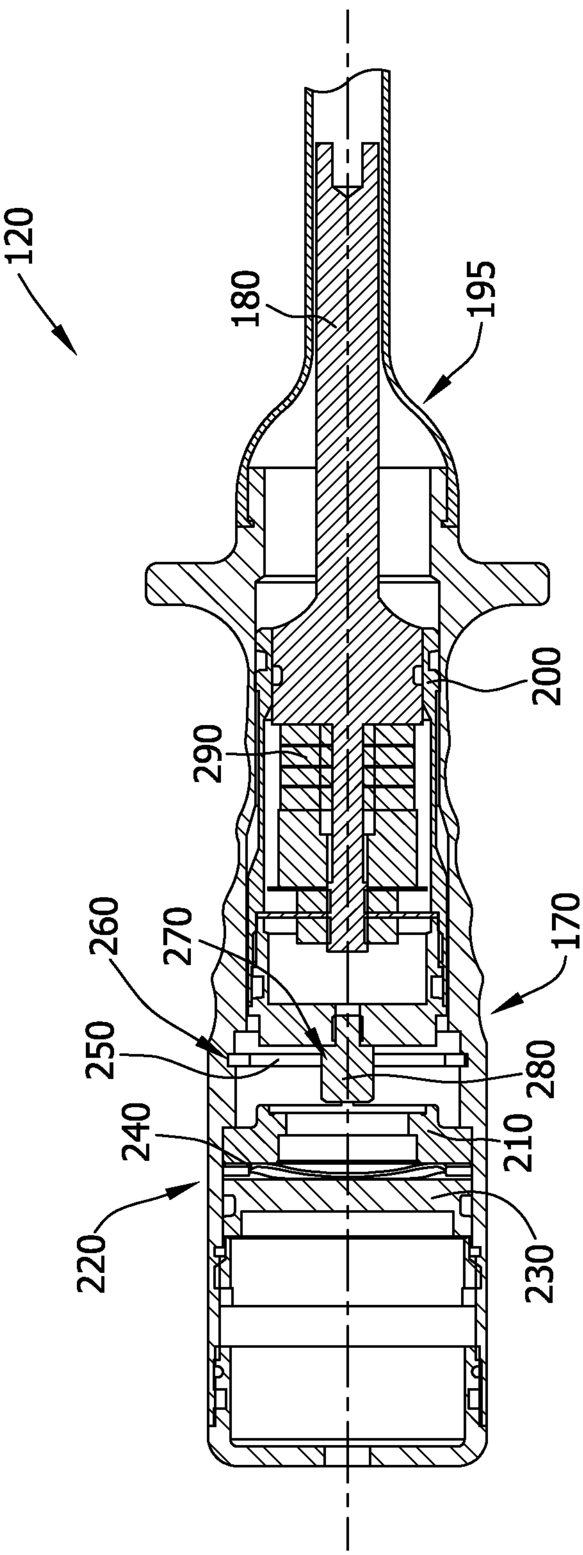


FIG. 2

FIG. 3

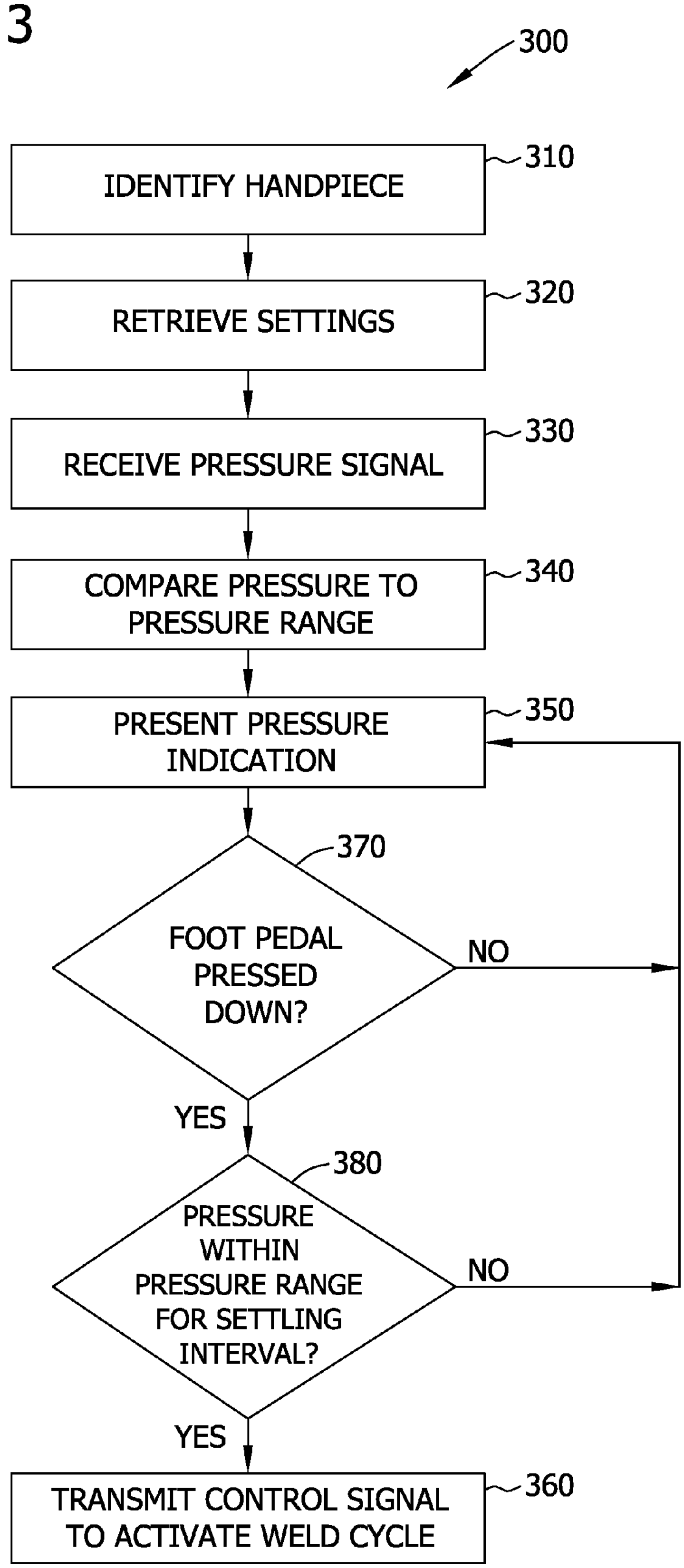
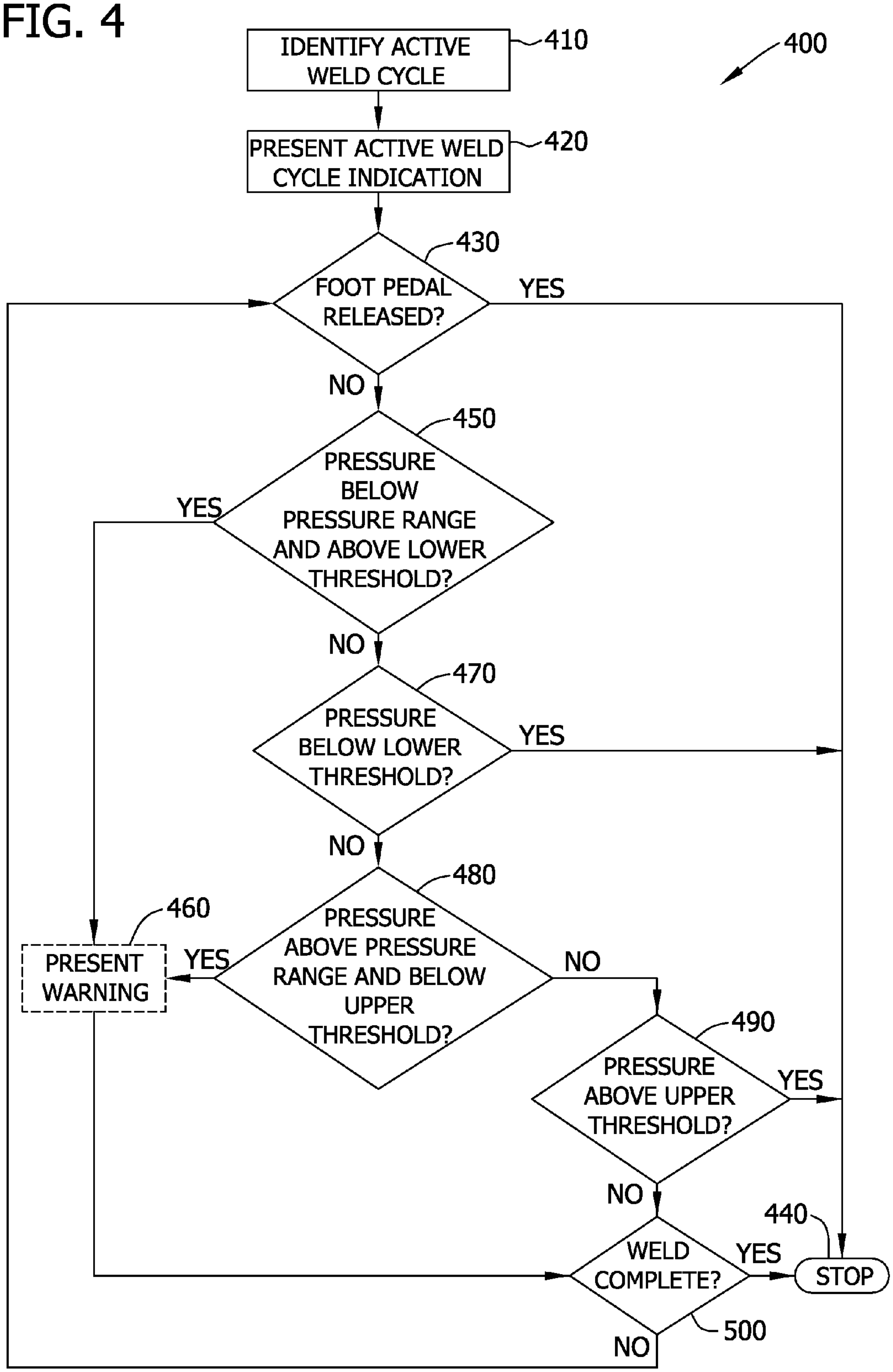

300
IDENTIFY HANDPIECE
310
RETRIEVE SETTINGS
320
RECEIVE PRESSURE SIGNAL
330
COMPARE PRESSURE TO PRESSURE RANGE
340
PRESENT PRESSURE INDICATION
350
FOOT PEDAL PRESSED DOWN?
370
NO
YES
PRESSURE WITHIN PRESSURE RANGE FOR SETTLING INTERVAL?
380
NO
YES
TRANSMIT CONTROL SIGNAL TO ACTIVATE WELD CYCLE
360

FIG. 4


400
IDENTIFY ACTIVE WELD CYCLE
410
PRESENT ACTIVE WELD CYCLE INDICATION
420
FOOT PEDAL RELEASED?
430
YES
NO
PRESSURE BELOW PRESSURE RANGE AND ABOVE LOWER THRESHOLD?
450
YES
NO
PRESSURE BELOW LOWER THRESHOLD?
470
YES
NO
PRESSURE ABOVE PRESSURE RANGE AND BELOW UPPER THRESHOLD?
480
YES
NO
PRESENT WARNING
460
PRESSURE ABOVE UPPER THRESHOLD?
490
YES
NO
WELD COMPLETE?
500
YES
NO
STOP
440

METHODS AND SYSTEMS FOR CONTROLLING AN ULTRASONIC HANDPIECE BASED ON SENSED PRESSURE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 61/496,147 filed Jun. 13, 2011, U.S. Provisional Patent Application No. 61/526,182 filed Aug. 22, 2011, and U.S. Provisional Patent Application No. 61/526,207 filed Aug. 22, 2011, which are hereby incorporated by reference in their respective entireties.

BACKGROUND

The present disclosure relates generally to medical devices and, more particularly, to methods and systems for controlling a handpiece based on sensed pressure.

Various types of known medical procedures involve repair and stabilization of body tissue. Such medical procedures may be utilized, for example, to treat conditions, such as, without limitation, a defect, damage, or fracture to bone, damaged or torn muscle, ligament or tendon, or separation of body tissues, etc. For example, fractured bones often involve stabilization of the bone in order to promote healing. Different bones and/or different types of fractures generally require unique procedures and/or surgical implements to facilitate stabilization of the body tissue. Accordingly, medical personnel employ a variety of surgical implements, such as screws, plates, and rods, to stabilize the bone across the fracture. In another example, further surgical implements may be used to anchor torn ligaments or tendons to other appropriate body tissue. As such, a variety of medical procedures and surgical implements are known to be used within the body of a patient to facilitate repair, stabilization, and/or healing of body tissue.

BRIEF SUMMARY

In one aspect, a method is provided for controlling a handpiece. The method includes receiving a pressure signal from the handpiece. The pressure signal is indicative of a pressure between the handpiece and a surgical implement. The method further includes determining the pressure between the handpiece and the surgical implement, comparing the pressure to a predetermined pressure range, and transmitting a control signal to the handpiece when the pressure is within the predetermined pressure range.

In another aspect, a surgical generator is provided for use with a handpiece. The surgical generator includes a processing device, and a memory device having encoded thereon computer-readable instructions that are executable by the processing device to perform functions including receiving a pressure signal from the handpiece. The pressure signal is indicative of a pressure between the handpiece and a surgical implement. The functions further include determining the pressure between the handpiece and the surgical implement, comparing the pressure to a predetermined pressure range, and transmitting a control signal to the handpiece when the pressure is within the predetermined pressure range.

In yet another aspect, a system is provided. The system includes a handpiece configured to generate vibratory energy, and a generator coupled to the handpiece. The generator includes a processing device and a memory device having encoded thereon computer-readable instructions that are executable by the processing device to perform functions

including receiving a pressure signal from the handpiece. The pressure signal is indicative of a pressure between the handpiece and a surgical implement. The functions further include determining the pressure between the handpiece and the surgical implement, comparing the pressure to a predetermined pressure range, and transmitting a control signal to the handpiece when the pressure is within the predetermined pressure range.

The features, functions, and advantages described herein may be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments, further details of which may be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1-4** show exemplary embodiments of the methods and systems described herein.

FIG. **1** is a schematic illustration of an exemplary surgical system;

FIG. **2** is a cross-sectional view of an exemplary handpiece that may be used with the surgical system shown in FIG. **1**;

FIG. **3** is a flowchart of an exemplary method of controlling the surgical system shown in FIG. **1**; and

FIG. **4** is a flowchart of another exemplary method of controlling the surgical system shown in FIG. **1**.

Although specific features of various embodiments may be shown in some drawings and not in others, this is for convenience only. Any feature of any drawing may be referenced and/or claimed in combination with any feature of any other drawing.

DETAILED DESCRIPTION

The present disclosure relates generally to medical devices and, more particularly, to methods and systems for controlling handpieces based on sensed pressure. In one embodiment, a generator receives a pressure signal from a handpiece. The pressure signal is indicative of a pressure between the handpiece and a surgical implement. The pressure is compared to a predetermined pressure range, and a control signal is transmitted to the handpiece when the pressure is within the predetermined pressure range. The handpiece generates vibratory energy, which is transmitted to the surgical implement.

Exemplary technical effects of the methods and systems described herein may include at least one of (a) identifying a handpiece based on an identifier; (b) retrieving at least one setting for the handpiece based on the identifier; (c) determining whether the handpiece is in an active weld cycle; (d) receiving a pressure signal from the handpiece; (e) determining the pressure between the handpiece and a surgical implement; (f) comparing the pressure to a predetermined pressure range; (g) providing at least one indication associated with the pressure; (h) determining whether the pressure has settled within the predetermined pressure range for at least a predetermined settling interval; (i) determining whether a foot pedal is depressed; and (j) transmitting a control signal to the handpiece.

As used herein, an element or step recited in the singular and preceded with the word "a" or "an" should be understood as not excluding plural elements or steps unless such exclusion is explicitly recited. Moreover, references to "one embodiment" and/or the "exemplary embodiment" are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

FIG. **1** shows an exemplary surgical system **100** including a surgical generator **110** and a handpiece **120**, which may be removably coupled to surgical generator **110**. Alternatively, surgical generator **110** may be integrated with handpiece **120**. As used herein, surgical and/or surgery are used to generally refer to any medical procedure involving a patient (a human being, an animal, etc.) and may include in-patient procedures, out-patient procedures, invasive procedures, non-invasive procedures, and/or minimally invasive procedures. In at least some embodiments, surgical implements (not shown) are disposed within the patient's body in orientations suitable for a respective medical procedure, such as a fracture stabilization procedure. Surgical implements may include implants or other suitable medical devices such as, without limitation, pins, screws, fasteners, dowels, rods, plates, and/or anchors. Moreover, as used herein, handpiece is used to generally refer to a housing, casing, frame, holder, and/or support that can be manually carried and manipulated during a medical procedure involving a patient.

In the exemplary embodiment, surgical generator **110** includes a processing device **130** and a memory device **140** coupled to processing device **130**. Processing device **130** may include, without limitation, a microcontroller, a microprocessor, a programmable gate array, an application specific integrated circuit (ASIC), a logic circuit, and/or any other circuit, integrated or otherwise, suitable to perform as described herein. Memory device **140** includes one or more devices operable to enable information such as executable instructions and/or other data to be stored and/or retrieved. Memory device **140** may include one or more computer readable media including, without limitation, hard disk storage, optical drive/disk storage, removable disk storage, flash memory, non-volatile memory, ROM, electrically-erasable programmable read-only memory (EEPROM), and/or random access memory (RAM). Memory device **140** is used to store one or more of predetermined thresholds, resonant frequencies, settings specific to handpiece **120**, and/or executable instructions.

In the exemplary embodiment, surgical generator **110** includes an output device **150** for example, a cathode ray tube (CRT), a liquid crystal display (LCD), an LED display, an "electronic ink" display, and/or other device suitable to display information to an operator. Additionally, output device **150** may include an audio output device (e.g., a speaker, etc.) to indicate verbal instructions, alerts, and/or warnings to the operator.

In the exemplary embodiment, surgical generator **110** includes one or more input devices, such as, without limitation, a button, a pedal, a knob, a keypad, a pointing device, a mouse, a touch sensitive panel (e.g., a touch pad or a touchscreen), a gyroscope, a position detector, and/or an audio input (e.g., a microphone). For example, in the exemplary embodiment, a foot pedal **160** is removably coupled to surgical generator **110** to enable an operator to provide input to surgical generator **110**. In one embodiment, the input device is integrated with surgical generator **110**. In another embodiment, the input device is remote from surgical generator **110** and coupled thereto.

Different types of handpieces **120** may be used with surgical generator **110** based on a type of medical procedure and/or a type of surgical implement. For example, various handpieces **120** may have different configurations and/or properties (e.g., acoustical characteristics, resonance frequency), and/or various surgical implements may require handpieces **120** of different sizes and/or configurations. In the exemplary embodiment, an identifier (not shown) enables surgical generator **110** to automatically identify handpiece **120**. For example, surgical generator **110** may read and/or detect a resistance identification, an RFID tag, and/or another identifying component to differentiate handpiece **120** from other handpieces **120**. Additionally or alternatively, an operator may manually identify handpiece **120**. In at least some embodiments, the identifier is associated with multiple medical procedures and/or surgical implements. In such embodiments, the operator may provide, and surgical generator **110** may receive, one or more inputs to select a medical procedure to be performed and/or a surgical implement to be interfaced.

In this manner, one or more handpieces **120** may be replaced between medical procedures. In at least some embodiments, handpiece **120** is removed after each patient such that handpiece **120** may be autoclaved between medical procedures to substantially ensure sterility for one or more subsequent patients. Accordingly, handpiece **120** is configured to withstand multiple autoclave procedures.

In the exemplary embodiment, handpiece **120** includes an outer housing **170**, a horn **180** extending longitudinally from outer housing **170**, an end effector **190** coupled to horn **180**, and a sheath **195** (shown in FIG. **2**) coupled to outer housing **170** and extending about and spaced radially from horn **180** and/or end effector **190**. In the exemplary embodiment, horn **180** and/or end effector **190** are sized and/or configured to slide within sheath **195**. In at least some embodiments, end effector **190** is integrated with horn **180**. In the exemplary embodiment, handpiece **120** is useable to affect one or multiple surgical implements during a surgery. More specifically, handpiece **120** applies vibratory energy, such as ultrasonic energy, to one or more of the surgical implements to form a weld between the surgical implements. Alternatively, handpiece **120** may apply any energy that enables surgical generator **110** and/or handpiece **120** to function as described herein.

In the exemplary embodiment, handpiece **120** is configured to provide an ergonomic interaction with an operator including, without limitation, a surgeon, a doctor, a surgery assistant, a nurse, a veterinarian, and/or other medical personnel present for a medical procedure. Other shapes and/or sizes of handpiece **120** may be included in other surgical system embodiments. In at least some embodiments, handpiece **120** is configured to interact with and/or be utilized by a robotic arm for robotic and/or remote control of handpiece **120**.

FIG. **2** is a cross-sectional view of handpiece **120**. In the exemplary embodiment, outer housing **170** houses at least an inner housing **200** and at least a portion of a transducer system or, more specifically, load cell **210**. In the exemplary embodiment, load cell **210** is configured to detect a first force and/or pressure applied to load cell **210** and transmit to surgical generator **110** (shown in FIG. **1**) a pressure signal associated with and/or indicative of the first pressure. The first pressure is associated with a force and/or pressure between end effector **190** (shown in FIG. **1**) and a surgical implement in contact with end effector **190**, which, in turn, directly applies a force and/or pressure to horn **180**.

In the exemplary embodiment, a biasing mechanism **220** is positioned within outer housing **170** to counteract, reduce and/or limit the first pressure applied to load cell **210**. More specifically, biasing mechanism **220** is moveable between an unflexed or home position and a flexed position. As the first pressure applied to load cell **210** generally increases, in the exemplary embodiment, biasing mechanism **220** moves towards the flexed position. Conversely, as the first pressure applied to load cell **210** generally decreases, in the exemplary embodiment, biasing mechanism **220** moves towards the home position. In the exemplary embodiment, biasing mechanism **220** includes a spring plate **230** and a wave spring **240** that is configured to compress as the first pressure increases and/or expand as the first pressure decreases. Alternatively, any type of biasing mechanism **220** may be used that enables handpiece **120** to function as described herein.

In the exemplary embodiment, outer housing **170** defines a cavity therein that is sized and/or configured such that inner housing **200** is retained within outer housing **170**. More specifically, outer housing **170** and/or inner housing **200** includes at least one retaining mechanism **250** that facilitates counteracting, reducing, and/or limiting the first pressure applied to load cell **210**. For example, in the exemplary embodiment, retaining mechanism **250** is positioned within outer housing **170** between inner housing **200** and load cell **210** to prevent and/or limit inner housing **200** from moving towards load cell **210** beyond a predetermined position. In the exemplary embodiment, a portion of retaining mechanism **250** is positioned at the predetermined position within a groove **260** defined by an inner surface of outer housing **170**. In the exemplary embodiment, retaining mechanism **250** includes an opening **270** extending longitudinally therethrough, and a standoff **280** coupled to inner housing **200** extends through opening **270** such that standoff **280** is configured to directly apply the first pressure to load cell **210**. Alternatively, any type of retaining mechanism **250** may be used that enables handpiece **120** to function as described herein.

In the exemplary embodiment, inner housing **200** houses at least a portion of horn **180** and at least a portion of a transducer system or, more specifically, vibrating mechanism **290** coupled to horn **180**. In the exemplary embodiment, vibrating mechanism **290** is a piezoelectric stack that is configured to generate vibratory energy (e.g., ultrasonic energy) upon receiving a control signal to activate a weld cycle. In the exemplary embodiment, horn **180** is configured to transmit the vibratory energy to an operative site. More specifically, horn **180** is coupleable to end effector **190** such that the vibratory energy is transmitted to end effector **190** through horn **180**. Alternatively, the vibratory energy may be transmitted to the operative site using any mechanism that enables handpiece **120** to function as described herein.

The transducer system includes at least vibrating mechanism **290** and load cell **210**. In this manner, the transducer system is configured to detect the first pressure, transmit the pressure signal, and generate ultrasonic vibratory energy. In the exemplary embodiment, vibrating mechanism **290** is remote from load cell **210**. Alternatively, vibrating mechanism **290** may be adjacent and/or integrated with load cell **210**.

In at least some embodiments, handpiece **120** includes a series of electrical contacts that are coupled to vibrating mechanism **290**. In such embodiments, the electrical contacts are moveable between a closed configuration and an open configuration such that the electrical contacts are electrically and/or communicatively coupled and/or decoupled, respectively. In such embodiments, as pressure applied to end effector **190**, horn **180**, and/or load cell **210** generally increases, the electrical contacts move toward the closed configuration, thereby coupling surgical generator **110** to vibrating mechanism **290**. Conversely, as pressure applied to end effector **190**, horn **180**, and/or load cell **210** generally decreases, in such embodiments, the electrical contacts move toward the open configuration, thereby decoupling surgical generator **110** from vibrating mechanism **290**. Alternatively, the electrical contacts may be positioned anywhere within handpiece **120** that enables surgical system **100** to function as described herein.

FIG. **3** is a flowchart of an exemplary method **300** of controlling surgical system **100**. During operation, in the exemplary embodiment, handpiece **120** is identified **310** based on an identifier and/or selected based on a type of medical procedure and/or surgical implement. In the exemplary embodiment, surgical generator **110** retrieves **320** one or more settings associated with handpiece **120**, the medical procedure, and/or the surgical implement from memory device **140** based on the identifier. The settings are used by surgical generator **110** to provide one or more control signals to handpiece **120**. Settings retrieved from memory device **140** may include, without limitation, frequencies, voltages, currents, and/or control algorithms. For example, in the exemplary embodiment, the setting retrieved from memory device **140** includes a predetermined first force and/or pressure range that enables vibratory energy transfer to the surgical implement, as described below.

Upon identification **310** and/or selection of handpiece **120** and retrieval **320** of one or more settings from memory device **140**, surgical system **100** is generally ready to affect the surgical implement. In the exemplary embodiment, end effector **190** is positioned at least partially within the patient and in contact with the surgical implement. More specifically, the operator uses handpiece **120** to apply force and/or pressure to the surgical implement, which, in turn, applies a force and/or pressure to horn **180** and inner housing **200**. As a result, standoff **280** applies the first pressure to load cell **210**, which detects the first pressure and transmits the pressure signal from handpiece **120** to surgical generator **110**.

In the exemplary embodiment, surgical generator **110** receives **330** the pressure signal from handpiece **120** and compares **340** the pressure between end effector **180** and the surgical implement, as indicated by the pressure signal, to the first pressure range. More specifically, surgical generator **110** determines a pressure based on the pressure signal, and the pressure is compared to the pressure range. When the pressure is outside of the first pressure range, surgical generator **110** does not transmit a control signal to activate a weld cycle, thereby inhibiting welding when undesirable pressure is applied. In the exemplary embodiment, the pressure is within the first pressure range when the axial force applied to handpiece **120** is between approximately 30 newtons (N) and approximately 38 N. Alternatively, the first pressure range may be associated with any force that enables handpiece **120** to function as described herein.

In at least some embodiments, output device **150** presents and/or provides **350** an indication of the pressure to the operator. For example, in one embodiment, a visual display provides **350** a visual indication of the applied pressure relative to the first pressure range such that the operator is able to visualize what, if any, corrections need to be made in order to provide a pressure within the first pressure range. Additionally or alternatively, an audio output device provides **350** an audible tone indicative of the applied pressure, and/or a tactile output device provides **350** vibrations indicative of the applied pressure. The tone and/or vibrations may include three rates, volumes, and/or intensities: a first rate, volume, and/or intensity indicating the pressure is below the first pressure range, a second rate, volume, and/or intensity indicating the pressure is within the first pressure range, and a third rate, volume, and/or intensity indicating the pressure is above the first pressure range. As such, the audible tone and/or the vibrations enable the operator to understand the applied pressure relative to the first pressure range without diverting the operator's visual attention from the patient and/or surgical implement.

In the exemplary embodiment, when the pressure is below the first pressure range, output device **150** provides **350** no visual or audible indicator. When the pressure is within the first pressure range, output device **150** provides **350** a ready light and a beep that is emitted at one second intervals. When the pressure is above the first pressure range, output device **150** provides **350** an "over pressure" display and a beep that is emitted at half-second intervals. Alternatively, output device **150** may provide any indication to the operator that enables surgical system **100** to function as described herein.

In the exemplary embodiment, when the applied pressure is within the first pressure range, the operator presses foot pedal **160** down to initiate transmission of the control signal to activate a weld cycle. More specifically, surgical generator **110** transmits **360** the control signal to handpiece **120** upon determining and/or identifying that the applied pressure is within the first pressure range and/or determining and/or identifying **370** that foot pedal **160** is depressed. In one embodiment, the control signal is transmitted **360** to handpiece **120** upon receiving the first indication that the applied pressure is within the first pressure range and then receiving the second indication that foot pedal **160** is depressed. In another embodiment, the control signal is transmitted **360** to handpiece **120** upon receiving the second indication that foot pedal **160** is depressed and then receiving the first indication that the applied pressure is within the first pressure range.

In at least some embodiments, surgical generator **110** requires that the applied pressure settle within the first pressure range for a predetermined settling interval. More specifically, surgical generator **110** determines and/or identifies **380** whether the applied pressure has settled within the first pressure range for a duration that is at least equal to the settling interval. As used herein, settling is used herein to generally refer to stabilizing and/or staying within a range. The settling interval encourages the operator to provide a consistent pressure within the first pressure range prior to transmitting the control signal to activate a weld cycle. In this manner, the settling interval enables consistent and proper welding to be provided between surgical implements, as compared to known surgical systems. In the exemplary embodiment, the settling interval is approximately 2.0 seconds. Alternatively, surgical generator **110** may utilize any settling interval that enables surgical system **100** to function as described herein.

In the exemplary embodiment, vibrating mechanism **290** receives the control signal to activate a weld cycle and generates vibratory energy upon receiving the control signal. The vibratory energy is transferred through horn **180** and end effector **190** to the surgical implement. The vibratory energy propagates through the surgical implement to vibrate the surgical implement and an adjacent surgical implement, which generates heat and a weld therebetween.

FIG. **4** is a flowchart of an exemplary method **400** of controlling surgical system **100** during an active weld cycle. In the exemplary embodiment, surgical generator **110** determines and/or identifies **410** that surgical system **100** is in the active weld cycle. During operation of handpiece **120** in the active weld cycle, output device **150** provides **420** an indication of the active weld cycle to the operator. For example, in one embodiment, an audio output device provides **390** an audible tone indicative of the active weld cycle. In the exemplary embodiment, when foot pedal **160** is released during the active weld cycle, surgical generator **110** determines and/or identifies **430** that foot pedal **160** is released and stops **440** transmission of the control signal and/or transmits a second control signal to stop the active weld cycle.

When surgical generator **110** determines and/or identifies **450** that the applied pressure is below a predetermined second pressure range and above a predetermined lower threshold during the active weld cycle, output device **140** may provide **460** a warning during and/or at the end of the weld cycle. When surgical generator **110** determines and/or identifies **470** that the applied pressure is at or below the lower threshold during the active weld cycle a stop state, surgical generator **110** may stop **440** transmission of the control signal and/or transmit a second control signal to stop the active weld cycle. In the exemplary embodiment, the applied pressure is within the second pressure range when the axial force applied to handpiece **120** is between approximately 0 N and approximately 50 N, and the lower threshold is approximately 0 N. In this manner, surgical generator **110** stops **440** transmission of the control signal and/or transmits a second control signal to stop the active weld cycle when the applied pressure is below the second pressure range in the exemplary embodiment. Alternatively, the second pressure range and/or the lower threshold may be associated with any force that enables handpiece **120** to function as described herein.

Moreover, when surgical generator **110** determines and/or identifies **480** that the applied pressure is above the second pressure range and below a predetermined upper threshold during the active weld cycle, output device **140** may provide **460** a warning during and/or at the end of the weld cycle. When surgical generator **110** determines and/or identifies **490** that the applied pressure is at or above the upper threshold during the active weld cycle, surgical generator **110** stops **440** stops transmission of the control signal and/or transmits a second control signal to stop the active weld cycle. In the exemplary embodiment, the applied pressure is within the second pressure range when the axial force applied to handpiece **120** is between approximately 0 N and approximately 50 N, and the upper threshold is undefined (i.e., surgical generator **110** does not recognize an upper threshold in the exemplary embodiment). In this manner, surgical generator **110** provides **460** a warning during and/or at the end of the weld cycle when the applied pressure is above the second pressure range in the exemplary embodiment. Alternatively, the second pressure range and/or the upper threshold may be associated with any force that enables handpiece **120** to function as described herein.

In the exemplary embodiment, the active weld cycle stops when the weld is complete. More specifically, surgical generator **110** determines and/or identifies **500** that the weld is complete based on a predetermined amount of energy or work applied by handpiece **120**, and stops **440** transmission of the control signal and/or transmits a second control signal to stop the active weld cycle when the weld is complete. In the exemplary embodiment, the amount of energy applied to the surgical implement is approximately 100 Joules (J). Alternatively, surgical generator **110** may apply any amount of energy that enables surgical system **100** to function as described herein.

The embodiments described herein relate generally to medical devices and, more particularly, to methods and systems for controlling a handpiece based on sensed pressure. The embodiments described herein monitor forces and/or pressures applied to a handpiece, its components, and/or a surgical implement. As such, the embodiments described herein facilitate creating effective and/or reliable welds, thereby improving a repair, stabilization, and/or healing time associated with the patient.

Exemplary embodiments of handpieces are described above in detail. The methods and systems are not limited to the specific embodiments described herein, but rather, components of systems and/or steps of the method may be utilized independently and separately from other components and/or steps described herein. Each method step and each component may also be used in combination with other method steps and/or components. Although specific features of various embodiments may be shown in some drawings and not in others, this is for convenience only. Any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

This written description uses examples to disclose the embodiments, including the best mode, and also to enable any person skilled in the art to practice the embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A method of controlling a handpiece, said method comprising:

receiving a pressure signal from the handpiece, the pressure signal indicative of a manually applied pressure generated by a user of the handpiece between the handpiece and the surgical implement by pressing the handpiece against the surgical implement;

determining the pressure between the handpiece and the surgical implement;

comparing the pressure to a predetermined pressure range;

transmitting a signal to the handpiece causing the handpiece to transmit vibratory energy to the surgical implement to form a weld to stabilize body tissue with the weld when the determined pressure is within the predetermined pressure range indicating the manually applied pressure between the handpiece and the surgical implement is suitable for forming the weld; and

determining whether the pressure has settled within the predetermined pressure range for at least a predetermined settling interval, wherein transmitting the signal further comprises transmitting the signal to the handpiece when the pressure has settled within the predetermined pressure range for at least the predetermined settling interval, wherein the predetermined settling interval is 2 seconds.

2. The method in accordance with claim **1** further comprising:

identifying the handpiece based on an identifier, the identifier being associated with at least one of multiple procedures and surgical implements; and

retrieving at least one setting for the handpiece based on the identifier.

3. The method in accordance with claim **1** further comprising providing at least one indication associated with the pressure.

4. The method in accordance with claim **1** further comprising:

providing a first indication when the pressure is below the predetermined pressure range;

providing a second indication when the pressure is within the predetermined range; and

providing a third indication when the pressure is above the predetermined pressure range.

5. The method in accordance with claim **1** further comprising determining whether a foot pedal is depressed, wherein transmitting the signal further comprises transmitting the signal to the handpiece when the pressure is within the predetermined pressure range and the foot pedal is depressed.

6. The method in accordance with claim **1** further comprising determining whether the handpiece is in an active weld cycle.

7. A surgical generator for use with a handpiece, said surgical generator comprising:

a processor; and

a memory device having encoded thereon computer-readable instructions that are executable by the processor to perform functions comprising:

receiving a pressure signal from the handpiece, the pressure signal indicative of a manually applied pressure generated by a user of the handpiece between the handpiece and a surgical implement by pressing the handpiece against the surgical implement;

determining the pressure between the handpiece and the surgical implement;

comparing the pressure to a predetermined pressure range;

transmitting a signal to the handpiece causing the handpiece to transmit vibratory energy to the surgical implement to form a weld to stabilize body tissue with the weld when the determined pressure is within the predetermined pressure range indicating the manually applied pressure between the handpiece and the surgical implement is suitable for forming the weld;

determining whether the pressure has settled within the predetermined pressure range for at least a predetermined settling interval; and

transmitting the signal to the handpiece when the pressure has settled within the predetermined pressure range for at least the predetermined settling interval, wherein the predetermined settling interval is 2 seconds.

8. The surgical generator in accordance with claim **7**, wherein the functions performed by the processor further comprise:

identifying the handpiece based on an identifier, the identifier being associated with at least one of multiple procedures and surgical implements; and

retrieving at least one setting for the handpiece based on the identifier.

9. The surgical generator in accordance with claim **7**, wherein the functions performed by the processor further comprise providing at least one indication associated with the pressure.

10. The surgical generator in accordance with claim **7**, wherein the functions performed by the processor further comprise:

providing a first indication when the pressure is below the predetermined pressure range;

providing a second indication when the pressure is within the predetermined range; and

providing a third indication when the pressure is above the predetermined pressure range.

11. The surgical generator in accordance with claim **7**, wherein the functions performed by the processor further comprise:

determining whether a foot pedal is depressed; and

transmitting the signal to the handpiece when the pressure is within the predetermined pressure range and the foot pedal is depressed.

12. The surgical generator in accordance with claim **7**, wherein the functions performed by the processor further comprise determining whether the handpiece is in an active weld cycle.

13. A system comprising:

a handpiece configured to generate vibratory energy; and

a generator coupled to the handpiece, the generator comprising a processor and a memory device having encoded thereon computer-readable instructions that are executable by the processor to perform functions comprising:

receiving a pressure signal from the handpiece, the pressure signal indicative of a manually applied pressure generated by a user of the handpiece between the handpiece and a surgical implement by pressing the handpiece against the surgical implement;

determining the pressure between the handpiece and the surgical implement;

comparing the pressure to a predetermined pressure range;

transmitting a signal to the handpiece causing the handpiece to transmit the vibratory energy to the surgical implement to form a weld to stabilize body tissue with the weld when the determined pressure is within the predetermined pressure range indicating the manually applied pressure between the handpiece and the surgical implement is suitable for forming the weld;

determining whether the pressure has settled within the predetermined pressure range for at least a predetermined settling interval; and

transmitting the signal to the handpiece when the pressure has settled within the predetermined pressure range for at least the predetermined settling interval, wherein the predetermined settling interval is 2 seconds.

14. The system in accordance with claim **13**, wherein the functions performed by the processor further comprise:

identifying the handpiece based on an identifier, the identifier being associated with at least one of multiple procedures and surgical implements; and

retrieving at least one setting for the handpiece based on the identifier.

15. The system in accordance with claim **13**, wherein the functions performed by the processor further comprise providing at least one indication associated with the pressure.

16. The system in accordance with claim **13**, wherein the functions performed by the processor further comprise:

determining whether a foot pedal is depressed; and

transmitting the signal to the handpiece when the pressure is within the predetermined pressure range and the foot pedal is depressed.

17. The system in accordance with claim **13**, wherein the functions performed by the processor further comprise determining whether the handpiece is in an active weld cycle.

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